A Risk-Based Vulnerability Approach for Rangeland Management

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In semiarid rangelands, continuous grazing may decrease vegetation cover, accelerate soil erosion and eventually cause a transition to an alternative, degraded state. State and Transition Models (STMs) illustrate possible changes in plant communities and soil properties and their interactions. They can be used to help decide where to monitor based on where change is most likely to occur. These key eco-hydrologic relationships govern the ecologic resilience of the various states and community phases on many rangeland Ecological Sites (ES) and are affected by management practices, land use, and disturbances. The future challenge for rangeland erosion modeling is to aid in the process of defining thresholds and assessing the risk of crossing a threshold between different ecological states.

The Rangeland Hydrology and Erosion Model (RHEM) Risk tool calculates the probability of occurrence of soil loss for any year to fall into the Low, Medium, High, or Very High categories. Low, Medium, High, and Very High thresholds are based on the 50^{th}, 80^{th}, and 95^{th} percentiles for probability of occurrence of soil loss for a user-defined baseline condition. To run the risk analysis, the user runs RHEM on each scenario or state condition (e.g., Historic Climax Plant Community (HCPC), Shrub cover dominated scenario, etc.), including one designated as a baseline from which others are compared. The soil erosion thresholds (β_1, β_2, β_3) are defined based on three recurrence intervals, 2-year, 5-year, and 20-year, respectively, for the baseline case. There is no consensus in the literature on the level at which events should be considered as extremes, so we divided the probability axis in four ranges for practical reasons, and provide a means for comparisons against the user-specified baseline condition.

We illustrate the use of the risk assessment approach at the Kendall Grassland site located in the Walnut Gulch Experimental Watershed (WGEW) in Tombstone, AZ. The mapping unit consists of a complex of Loamy Upland and Limy Slopes. The STM for the Limy Slopes 12-16" p.z. ES included 4 states: Historic Climax Plant Community (HCPC), Eroded, Shrub, and Lehmann Love Grass (hereafter referred to as Grass). Within the HCPC state, fire and drought could cause temporary shifts between two plants communities. The Eroded state is considered so degraded that it has crossed a threshold and now has a less productive plant community. Total foliar cover and total ground cover for each ecological state on the STM were: (HCPC=61%, Eroded=35%, Shrub=38%, Grass=38%); (HCPC=70%, Eroded=25%, Shrub=29%, Grass=54%), respectively.

RHEM was run with the same 300 years synthetic climate record for each state condition, which is standard in the RHEM interface. The 50^{th}, 80^{th}, and 95^{th} percentiles were extracted for the baseline case. Simulated average annual runoff depth and soil loss for each ecological state were: HCPC=12.42 (mm/yr), Eroded=22.22 (mm/yr), Shrub=21.20 (mm/yr), Grass=16.19 (mm/yr); HCPC=0.17 (t/ha/yr), Eroded=1.97 (t/ha/yr), Shrub=1.58 (t/ha/yr), Grass=0.35 (t/ha/yr), respectively, and the yearly occurrence probability for each state was found (Table 1).

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Annual soil loss thresholds, [β_1=0.10 (t/ha/yr), β_2=0.31 (t/ha/yr), and β_3=0.87 (t/ha/yr)], were estimated from the probability density function based on the reference state (HCPC).

Partial results of the RHEM risk output (Table 1) indicate that the 5-percent annual exceedance probability soil loss event (0.565 t/ha) has an 88 percent chance of occurring in the Eroded state in any given year. RHEM results suggest that this state falls in 88% of years within the Very High soil erosion damage class. In contrast, the 5-percent annual exceedance probability soil loss event (0.565 t/ha) has 24 percent chance of occurring in the Grass state in any given year. The mean annual soil loss (0.347 t/ha) of the Grass state falls in the Medium soil loss damage class.

Table 1. Probability of occurrence matrix.

Probability Risk Functions	**Soil Loss Damage Class**	**Probability of Occurrence**		
		HCPC	**Grass**	**Eroded**
prob ($X \leq 0.211$)	Low	0.500	0.289	0.026
prob ($0.211 < X \leq 0.386$)	Medium	0.300	0.319	0.042
prob ($0.386 < X \leq 0.565$)	High	0.150	0.150	0.057
prob ($X > 0.565$)	Very high	0.05	0.243	0.875