RESTORING DEGRADED RANGELANDS IN JORDAN: OPTIMIZING MECHANIZED MICRO WATER HARVESTING TECHNIQUE USING RANGELAND HYDROLOGY AND EROSION MODEL (RHEM)

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Introduction

Continuous population growth, recent refugee movement and migration as well as boundary restrictions and their implications on the nomadic lifestyle added pressure on the rangelands throughout the Middle East. In particular, overgrazing through increased livestock herds threatens the Jordanian rangelands – the so called Badia. Degradation of the native vegetation and soils harm the rainwater infiltration and retention and eventually accelerates surface runoff and erosion (Ben Khelifa et al., 2016). Recently, various projects have been launched aiming at restoring the degraded ecosystems. The present study focusses on the 'Vallerani plow' based mechanized WH technique, which creates micro-catchments along the contour in certain spacing - intersecting the hill slopes and enabling the out-planting of shrubs within the WH pits. Rangeland Hydrology and Erosion Model (RHEM; Nearing et al., 2011) was used to 1) validate and investigate water and sediment dynamics to 2) optimize the design of Vallerani WH system, and thus, to suggest on targeted micro-WH spacing considering various environmental conditions, Vallerani WH retention capacity, soil erosion pattern and the out-planted shrub seedling water demand over time.

Materials and Methods

Rangeland research site was established approximately 10km south-east of Amman (Figure 1) in the central Jordanian Badia. The climate is semi-arid; average annual rainfall is less than 200mm during the rainy season from October to May. Average annual maximum and minimum temperature are 23.5 C° and 11.3 C°, respectively. The soils have a silty-loam texture (top layer) - they are shallow and rocky at the hilltops and exceed 2m depth in the valley bottoms. Vegetation cover is sparse; only few percentage of the rangelands are covered with shrubs e.g., while large areas, particularly in the valley bottoms, are plowed and prepared for barley agriculture during the rainy season. Mechanized WH was implemented using 'Vallerani Delfino-Plow' system (Gammoh and Oweis, 2011). The Vallerani plow is a hydraulically operating single ridge moldboard plow with a deep-ripping sub-soiler, which allows deep fracturing of the soil and the creation of intermitted semi-circular WH structures (Figure 1). Depending on various climatic, terrain and soil specific parameters, the common spacing between the contours varies between 4m and 12m, and the plowing lengths of single WH structure usually varies between 1.6m and 4.7m. Along the contour, the hydraulic control-unit interrupts the semi-circular pits in approximately 0.7m to 2.3m spacing, depending on the machine adjustments and tractor driving speed (Gammoh and Oweis, 2011). The Vallerani WH structure has approximately 0.5m wide ridge and a 0.5m wide pit (cross section), while the plow generates approximately 0.3m deep pit and the top of the ridge usually exceeds the soil surface by 0.2-0.3m. In the research site, in each of the WH pits two native shrub seedlings (Atriplex) were out-planted supposed to develop vegetation islands for spread-out over time.

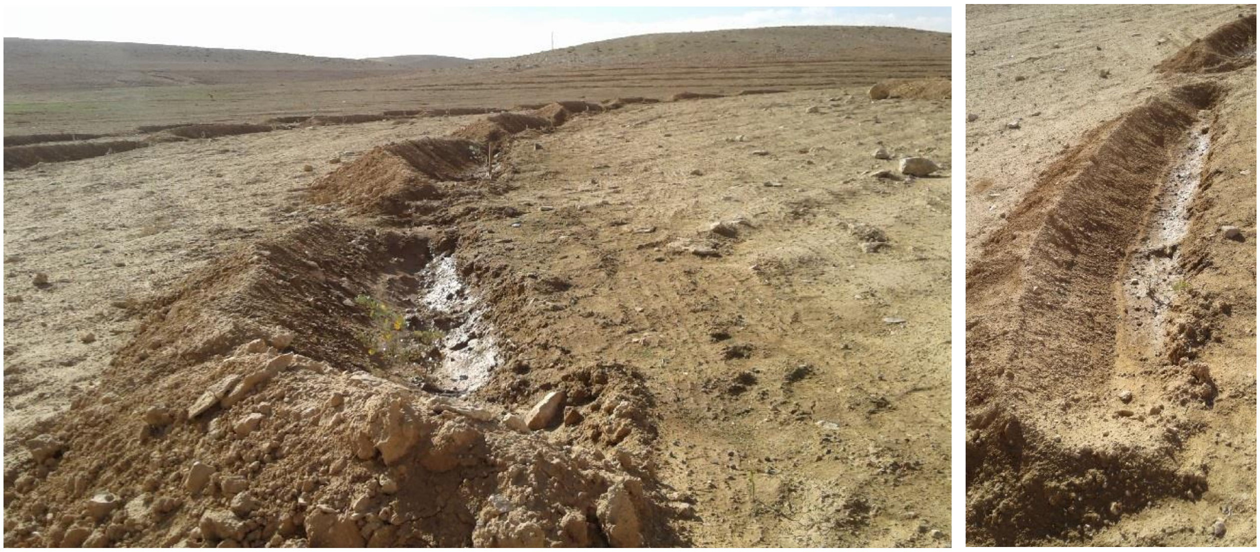

Figure 1. Vallerani WH design in Jordanian Badia research site, approximately 10km south-east of Amman.

Rangeland Hydrology and Erosion Model (RHEM; Nearing et al., 2011) was used to simulate runoff and erosion of the interspacing between the WH structures. Thus, to transparently optimize implementation distance considering (1) the minimum amount of harvested surface runoff related with the water requirements of the out-planted shrub (during first and second year of establishment), (2) destructive over-spilling of the Vallerani WH structure in case of extreme events, and (3) the cumulative soil erosion and consequential accumulation (WH storage loss) in the pit. RHEM performance was validated through runoff plot data obtained from local experiments in 2016 and 2017 (Figure 2).

Figure 2. Runoff plots established at Badia research site in Jordan.

Climate Generator CLIGEN, prepared for Jordan/Amman station (AMMAN JOR; ID: 40270) was used to simulate a 300-year time series of rainfall and consequential runoff and erosion events using RHEM.

Results and Discussion

Validation of RHEM through plot data obtained from rangeland experimental site indicated good modeling performance. Table 1 demonstrates observed versus modeled surface runoff based on seven (partly cumulative) events. Especially the few larger events, observed on 28th of January 2016 and from 3rd to 18th of December 2016, show a very good match.

Table 1. Rainfall and runoff events – observed vs. simulated (RHEM).

Date	Rainfall (mm)	Runoff (mm)	
		Observed	Simulated
01/28/2016	19.7	8.9	6.7
02/06/2016	1.7	1.0	0.0
02/07/2016	3.4		
02/22/2016	2.3		
03/17/2016	2.0	0.5	3.1
03/27/2016	18.2		
04/11/2016	3.1	2.3	0.0
04/14/2016	2.0		
12/03/2016	3.0	15.0	17.6
12/15/2016	20.0		
12/16/2016	4.8		
12/17/2016	2.3		
12/18/2016	31.9		
12/20/2016	12.4	5.3	1.0
12/25/2016	7.4	2.9	0.0
12/28/2016	2.9		

RHEM was forced through a 300-year rainfall time series generated by CLIGEN representing climatic conditions of Amman. Figure 3 shows the average annual runoff and erosion behavior considering Badia rangeland conditions for various hill slope lengths (Vallerani contour spacing) for a 10 percent hillslope.

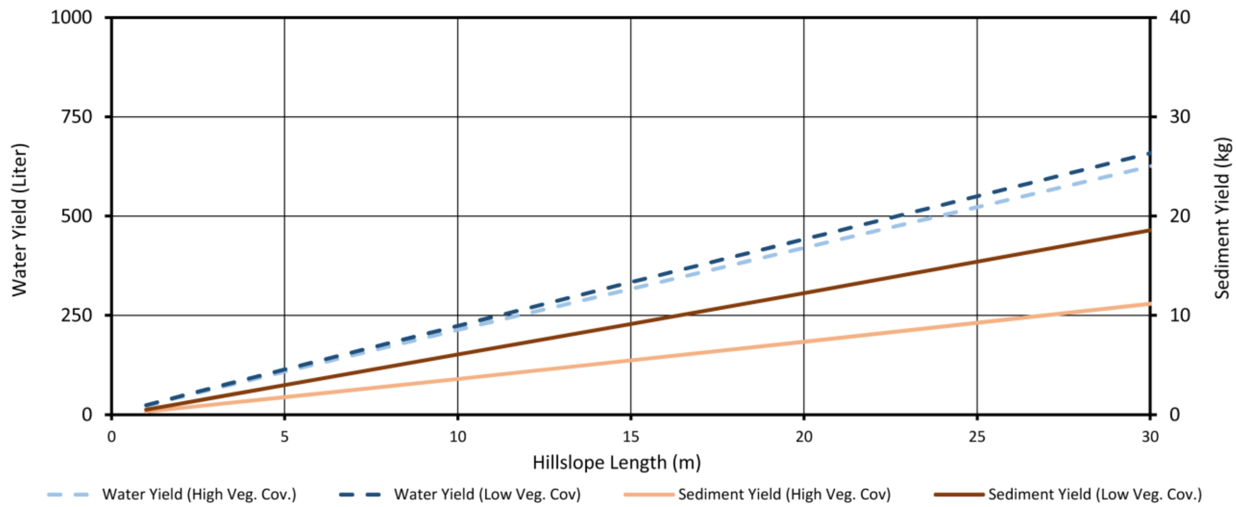

Figure 3. Relation of hillslope length and average annual water and sediment yield per 1m hillslope width.

However, proper Soil and Water Conservation (SWC) design requires the knowledge of the magnitudes and the occurrence probabilities of the events rather than average annual values (Strohmeier et al., 2016). A probabilistic risk assessment approach accounting for variable rangeland pattern will be presented at the CONSOWA in Lleida (Spain) in June 2017.

Conclusion

The study demonstrates that RHEM satisfactorily simulates surface runoff processes of a Jordanian rangeland (Badia) environment. Thus, RHEM can be used to predict surface water yields to water harvesting structures intermittingly implemented across degraded Jordanian landscape. A risk assessment approach will be developed considering variable thresholds of surface water yields, both minimum and maximum, as well as erosion and consequential sediment accumulation. This will support the decision making process for targeted Badia restoration efforts – towards a multi-criteria tool trading off shrub growth, soil conservation and biodiversity.

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