RUNOFF AND SEDIMENT SUPPLY FROM SMALL GULLIED AND UNGULLIED BASINS IN A SEMI-ARID GRAZED ENVIRONMENT

Chocron, M.*, Laronne, J.B. , Alexandrov, Y.

Department of Geography and Environmental Development, Ben-Gurion University of the Negev, POB 653, Beer-Sheva 84105, Israel.
*chocronm@bgu.ac.il

1. Introduction

The development of a channel network is both unsteady and nonuniform. The fluvial-morphology of rangelands is commonly characterized by headwater ephemeral stream channels and unchanneled valleys. These may incise, thereby forming gullies. The study of gully systems is important because they are a very significant source of sediment and are conduits for sediments and water in semi-arid environments (Poesen et al., 2002), transporting not only suspended sediment but also coarse bedload sedimentary fragments (Rustomji, 2006). Because high-intensity rainfall often generates Hortonian runoff in drylands, temporal correlation between hydrograph and hyetograph peaks is common.

The aim of the presented study is to determine links between rainfall, runoff, gully erosion and sediments. The extent of sediment yield (suspended sediment and bedload) and runoff response from gullied and ungullied basins have been explored. The outcomes of this study are discussed in the context of spatial and temporal scales.

2. Study area

The research is undertaken on a tributary of Nahal (Wadi) Bikhra, located on the southern edge of the Hebron Mountains and the northern fringe of the Negev desert. The climate is semi-arid with a mean annual precipitation of 230 mm. The landscape is characterized by rounded hills dissected by an intense channel network. Loess covers most of the area. Bedrock is Senonian chalk, limestone and some chert. The vegetation, mainly dwarf scrub and annual herbs is sparse, partly because of the intense grazing. Channel incision in the Bikhra is part of a natural regional process that started at the end of the Pleistocene, although accelerated incision has also been anthropic.

3. Methodology

We have monitored rainfall, runoff and sediment at the outlets of a 4th-order basin (0.6 km^2) termed FOB and four of its 1st-order tributaries (0.007-0.015 km^2). Two of these tributaries are gullied (NG & SG) and one pair is ungullied (NU & SU). The southern paired tributary basins (SG, SU) share a common divide and the northern are separated by one small 1st order basin. The two ungullied sub-basins have a denser vegetation cover (mainly shrubs) within their channels.

Miniature and recording rainfall gauges monitor rainfall in the sub-basins and at the basin outlet. Both hydrological and meteorological rainfall are recorded.

Water stage is monitored by pressure transducers at the basin and sub-basin outlets, placed inside a stilling well at stabilized (cemented) cross sections. Suspended sediment is automatically monitored by (1) an automatic water sampler at the basin outlet and (2) at each sub-basin in two cumulative 1.5 L bottles sampling at two flow depths (2 and 5 cm). Pit bedload samplers are located at the outlet of each of the sub-basins. The pits have a 110-mm slot width. Sediments from the pits were analyzed by wet and dry sieving for grain-size distribution. Bedload in this study is defined as sediment coarser than 0.125 mm.

Source of sediment and extent of erosional activity were determined by spray-painting bed material patches (20x20 cm) and 100*100 cm patches on hillslopes. Erosion pins were deployed into the loess above gully heads to determine gully head advancement.

4. Preliminary results

4.1. Rainfall and Runoff

This study has been conducted for the past two hydrologic years (2005-06 and 2006-07). One so-called Cyprus cyclone rainstorm (20-21 Jan., 2007) has been chosen during which all the monitored basins generated runoff. Average rainfall depth was 25 mm with maximum 1 and 5 min intensities of 33 and 13 mm/h, respectively The variation of rainfall between sub-basins was insignificant (±1.6 mm), but inter-basin variation of runoff was considerable (Fig. 1).

At FOB and SG altogether 5 runoff peaks were recorded while at NG and SU merely 3, whereas only one peak at NU. Runoff duration was largest at the basin outlet (FOB) and SG (nearly four hours). A rainfall intensity of 13 mm/h lasting 5 min was required for runoff response throughout the monitored basins. However, partial basin response was detected during rainfall of lesser intensity.

Maximum discharge in this event was 0.8, 1.3, 1.4 and 7.1 l/sec at the SU, NU, NG and SG, respectively. Runoff peak resulted due to maximum rainfall intensity; lag between maximum rainfall intensity and runoff was 11 min for FOB, 8 min for ungullied sub-basins and only 5-6 min for the gullied sub-basins.

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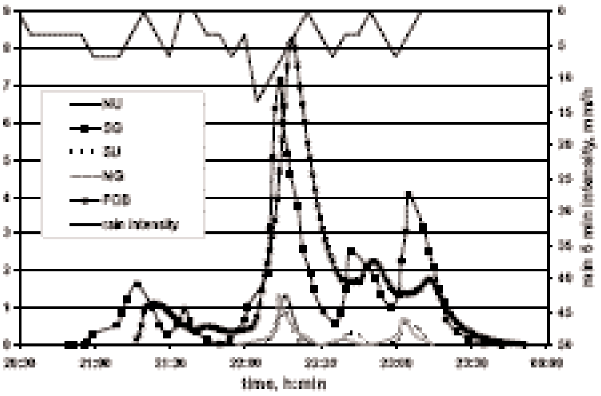
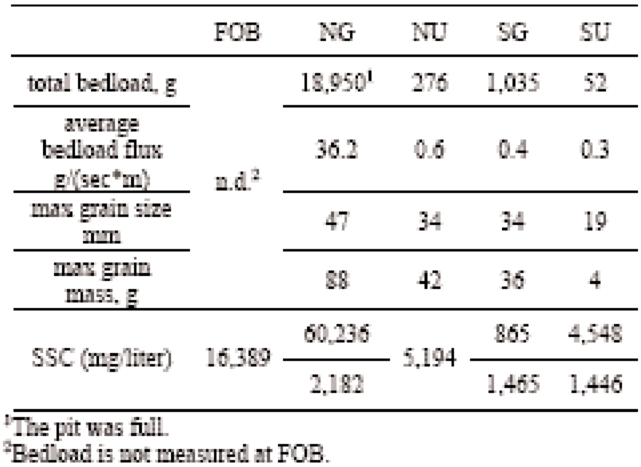


Fig. 1. Rainfall intensity and hydrographs of four 1st-order sub-basins (l/sec) and Fourth-Order Basin - FOB (0.1 m^3/sec) outlets on 20 January 2007.

4.2. Sediments

Suspended sediment concentration (SSC) generally increased with water depth (Table 1). Interestingly, the SSC in the larger FOB was higher than in its tributaries except the sample from NG at a relative high flow depth (5 cm at the sampling point and 2 cm at depth measurement point).

Table 1. Suspended sediment concentration (SSC), mass of bedload in pits, average bedload flux, size and mass of largest grains (average of three largest grains) sampled in pits on 20-21 Jan. 2007. The upper cells in the SSC row are samples from a larger flow depth (5 cm at the sampling point).



	FOB	NG	NU	SG	SU
total bedload, g	n.d.[2]	18,950[1]	276	1,035	52
average bedload flux g/(sec*m)		36.2	0.6	0.4	0.3
max grain size mm		47	34	34	19
max grain mass, g		88	42	36	4
SSC (mg/liter)	16,389	60,236	5,194	865	4,548
		2,182		1,465	1,446

[1] The pit was full.
[2] Bedload is not measured at FOB.

The bedload yield from the gullied basins (NG & SG) is significantly higher than in the ungullied counterparts (Table 1). The bedload in the NG pit was 70 times larger than at NU, while the bedload in the SG pit was 20 times that of SU. More than 50 percent of the sediment (by mass) in the pits is granules and pebbles. Differences in yield are considerably larger than in bedload size. Bedload in the NG pit included painted gravels from as far as the gully head (ca 60 m upstream), thereby demonstrating the high efficiency of the gully system to transport coarse sediment.

5. Discussion

Runoff inhomogeneity in space and in time is ascribed to differences in surface properties (e.g., crusting and vegetation cover). Part of the channel network development of a gullied valley is the decline in vegetal cover. The role of vegetation in our study is to allow high infiltration rates and to lower runoff velocity, including within gullied channel. This study demonstrates that ungullied basins have a higher rainfall threshold for runoff generation in comparison with the ungullied counterparts and, therefore, are more productive in sediment transport and yield.

Gullying process may be an important source for coarse sediment (bedload). In this study, bedload transport rate is lower in ungullied valleys than in gullied valleys. The small difference in bedload rate between the southern pair can be explained by different event duration. Observations at NG and other gullies show that the behavior of bedload movement in gullies is essentially a cut & fill process as in higher order channels. Because flow duration is short, this process occurs in few (1-2) events, during which the gully base may be incised and in the succeeding event it may fill.

The differences in SSC and bedload yield between the 1st order basins may represent their stages of development. The NG gullied basin is far more productive with fine sediment and bedload because the basin is unstable, whereas the SG gully is presently at a repairing condition and therefore is more stable and less sediment-productive. Both ungullied (NU & SU) basins are stabilized by vegetation with almost no remnants of incision.

The SSC in the 4th order channel is one magnitude higher than most of measured SSC in the 1st order channels, likely because at the higher scale the channel flow is characterized by higher shear stresses that erode channel bed and banks and thereby transport larger concentrations of suspended sediments.

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References

Poesen, J., Vandekerckhove, L., Nachtergaele, J., Oostwoud Wijdenes, D., Verstraeten, G. and Van Wesemal, B. 2002. Gully erosion in dryland environments. In Bull, L.J. and Kirkby M.J. (Ed.), *Dryland rivers: hydrology and geomorphology of semi-arid channels.* By, John Wiley & Sons: 229-262.

Rustomji, P. 2006. Analysis of gully dimensions and sediment texture from southeast Australia for catchment sediment budgeting. *Catena*, 67: 119-127.

Tucker, G.E., Arnold, L., Bras, R.L., Flores, H., Istanbulluoglu, E. and Sólyom, P. 2006. Headwater channel dynamics in semiarid rangelands, Colorado high plains, USA. *Geological Society of America,* 118: 959-974.