14th International Soil Conservation Organization Conference.
Water Management and Soil Conservation in Semi-Arid Environments. Marrakech, Morocco, May 14-19, 2006 (ISCO 2006).

Sediment Yield From Small Semiarid Watersheds

M. H. Nichols
USDA-ARS Southwest Watershed Research Center, Tucson, Arizona, USA, mnichols@tucson.ars.ag.gov

Abstract

Small watershed sediment yield data were evaluated for eight small watersheds ranging from 35.2 to 159.5 ha within the United States Department of Agriculture – Agricultural Research Service Walnut Gulch Experimental Watershed (WGEW) in southeastern Arizona, USA. Stock pond sediment accumulation measurements covering time periods from 30 to 47 years were combined with water level records and estimates of sediment transported in pond overflows to compute average annual sediment yields. Within the 150 km sq WGEW, sediment yield from upland watersheds ranged from 0.6 $t \cdot ha^{-1} \cdot yr^{-1}$ to 3.7 $t \cdot ha^{-1} \cdot yr^{-1}$. Sediment yields were temporally and spatially variable, which adds to the complexity of generalizing sediment yield rates across semiarid regions.

Introduction

Soil erosion and offsite sedimentation are recognized as problems throughout arid and semiarid and regions of the world. Watershed sediment yield can be measured directly through reservoir sedimentation surveys providing an integrated measure of soil erosion, sediment transport, and deposition. Unfortunately, data describing long-term sediment yield rates on semiarid rangeland watersheds are relatively rare.

Throughout the southwestern United States, stock ponds temporarily detain surface water for irrigation, livestock, flood control, and wildlife. In addition, they are a convenient downstream control point for measuring sediment accumulation and computing average annual sediment yield rates. This paper summarizes recent work to quantify sediment yield rates on small semiarid rangeland watersheds. Additional detail can be found in Nichols (2006).

Materials and Methods

Sediment yields were computed for eight small watersheds within the US Department of Agriculture Agricultural Research Service Walnut Gulch Experimental Watershed (WGEW) near Tombstone, Arizona (Fig. 1.) (Renard et al. 1993). The watersheds range in size from 35.2 to 159.5 ha (Table 1). Average annual precipitation on the WGEW ranges from 303 mm at the lower end of the watershed to 339 mm near the upper end. Precipitation during July, August, and September accounts for over 60% of the annual total and is characterized by high-intensity, short-duration airmass thunderstorms. These storms generate most of the surface runoff in the normally dry channels (Osborn 1983). Runoff into stock tanks at the outlet of each of the 8 watersheds is monitored with a water level recorder.

Sediment accumulation was measured through periodic topographic surveys of the surface of each stock pond when the ponds were dry. The measured differences in pond volume attributed to sediment influx were converted to sediment yields. Pond spills, although rare, occur frequently enough that sediment lost through spillway overflow was estimated and included in this analysis. Spill volumes were computed using standard weir formulae. Sediment reaching the outlet of each pond watershed included 1) the amount of sediment accumulated in each pond and 2) the amount of sediment that passed through each pond spillway during pond overflows. The total sediment yield from each watershed was determined by adding the sediment leaving through the spillway during overflows to the sediment accumulated in each pond.

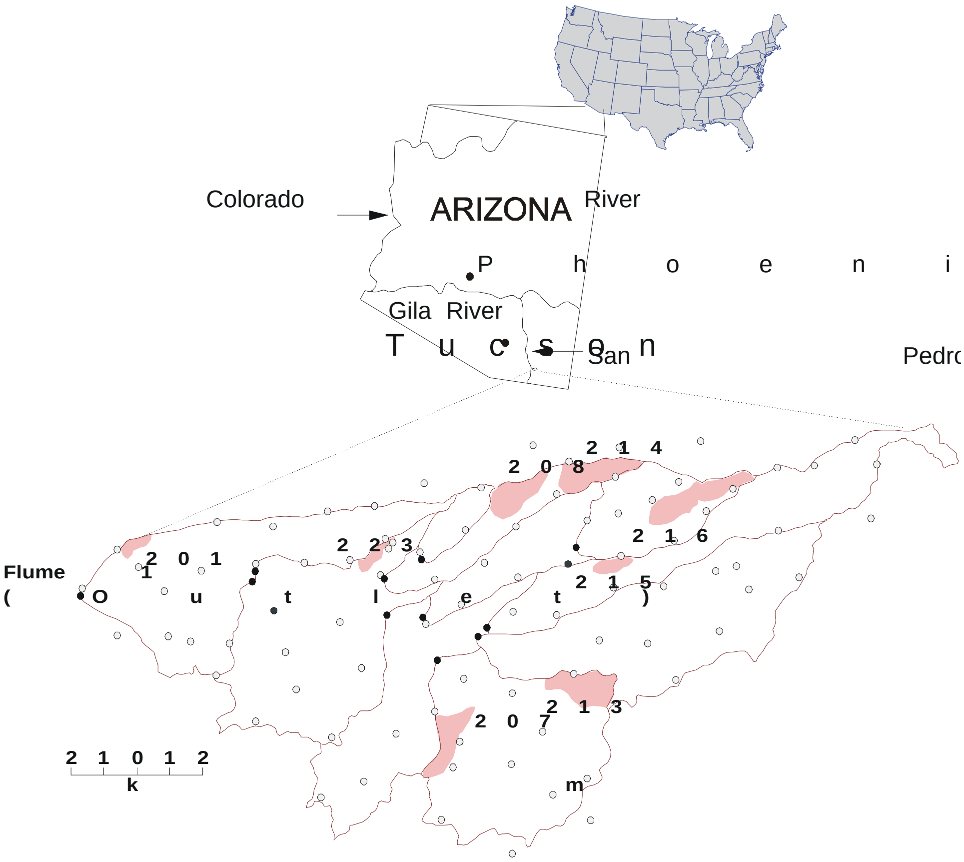

Figure 1. Walnut Gulch Experimental Watershed and stock pond location map

Results

Sediment yields computed on a per-hectare basis provide a means for comparing watersheds. Sediment yields are summarized in Table 1 and ranged from 0.6 $t \cdot ha^{-1} \cdot yr^{-1}$ to 3.7 $t \cdot ha^{-1} \cdot yr^{-1}$. When converted to denudation rates over the watersheds, this corresponds to a minimum of 1.8 mm of soil loss over the 159-ha Pond 213 watershed during the 35-year record, and a maximum of 14.0 mm over the 43.8-ha Pond 223 watershed during the 46-year record. However, it is not likely that the only source of the sediment delivered to the watershed outlets was eroding uplands, but there is insufficient data to fully quantify sources. Overall, 7% of the runoff events into the ponds resulted in spills, but in years when spills occur, the spill volume was 35% of the total runoff volume. Excluding Pond 213, the trap efficiency of studied ponds on the WGEW was relatively high, ranging from 76%–94%, and during individual years was often 100%.

Print

Proceedings

Table 1. Summary of sediment yields for stock pond watersheds within the Walnut Gulch Experimental Watershed.

Stock pond No.	Watershed Area (ha)	Years of record	Average bulk density ($g \cdot cm^{-3}$)	Average mass accumulated ($t \cdot yr^{-1}$)	Average mass through spillway ($t \cdot yr^{-1}$)	Average total mass ($t \cdot yr^{-1}$)	Average total mass ($t \cdot ha^{-1} \cdot yr^{-1}$)
201	44.0	35	1.37	34	4	38	0.9
207	110.8	41	1.11	53	10	63	0.6
208	92.2	30	1.18	43	13	56	0.6
213	159.5	39	1.20	11	78	89	0.6
214	150.5	46	1.19	285	24	309	2.1
215	35.2	37	1.29	104	7	111	3.1
216	84.2	41	1.21	172	19	191	2.3
223	43.8	47	1.23	146	15	161	3.7

Discussion and Conclusions

Stock ponds are ubiquitous across rangelands and they can provide valuable information on sediment yield rates from small watersheds. Average annual sediment yield values provide a temporally integrated measure of soil erosion and sediment transport processes and are a useful index for comparing among watersheds over long time periods. Common management practices for erosion control on rangelands are typically applied at the hillslope and subwatershed scale, and in reducing erosion they may affect sediment yield. Several factors add to the complexity in interpreting this information including: 1) spatial variability in water shed characteristics, 2) temporal variability in rainfall and runoff, and 3) the relationships among soil erosion, sediment transport, deposition, and yield processes.

Long-term sediment yield rates are related to runoff. However, interpretations of sediment yields need to be made in the context of local climate variability with careful attention to rainfall and runoff patterns during the period of record. In thunderstorm-dominated semiarid regions, the variability of sediment yield within an individual watershed in response to highly variable precipitation and runoff will be masked by temporally integrated long-term measurements. In contrast, measurement over short time periods may introduce significant bias into yield estimates if the measurement period happens to coincide with a period of drought or above average rainfall. As a result, average annual sediment yield rates may not provide sufficient information to interpret causes and effects of upland management over short time periods.

Finally, sediment yield values are an integrated measure of erosion, transport, and deposition processes. As such, they are not directly comparable to erosion rates. The processes that control erosion and sediment yield vary with scale. Hillslope erosion is controlled by factors such as slope and ground cover and is generally assessed for areas less than 10 ha, while sediment yield is usually assessed from watersheds based on measurement at the watershed outlet. At the watershed scale, sediment deposition and storage, both within the channel network and along toeslopes and floodplains can account for a considerable amount of eroded material. In addition, the efficiency with which the channel network conveys sediment through the watershed is a primary control on downstream delivery. These components of the sediment yield processes need to be quantified to understand the relationship between upland erosion and downstream sediment yield. Identifying the areas within a watershed where sediment production is the highest is a step toward focusing remediation efforts to reduce erosion.

This study summarizes sediment yields from subwatersheds within the WGEW since 1956 for periods of record ranging from 30 to 47 years. Sediment yields were variable in time and in space and ranged from 0.6 $t \cdot ha^{-1} \cdot yr^{-1}$ to 3.7 $t \cdot ha^{-1} \cdot yr^{-1}$. Although the reported sediment yield rates are not high with respect to those from cultivated agricultural regions, many rangeland soils are relatively shallow and denudation of the surface soil is a critical loss. In order to reach the goal of generalizing sediment yield rates across rangeland regions to help better implement management practices, additional research is necessary to determine the relative influence of rainfall and runoff patterns on semiarid rangeland sediment transport.

Literature Cited

Nichols, M. H. 2006. Measured Sediment Yield Rates From Semiarid Rangeland Watersheds. Rangeland Ecology and Management vol. 59(1) *in press*

Osborn, H. B. 1983. Precipitation characteristics affecting hydrologic response in southwestern rangelands. US Department of Agriculture, Agricultural Research Service Agricultural Reviews and Manuals ARM-W-34. 55 p.

Renard, K. G, L. J. Lane, J. R. Simanton, W. E. Emmerich, J. J. Stone, M. A. Weltz, D. C. Goodrich, and D. S. Yakowitz. 1993. Agricultural impacts in an arid environment: Walnut Gulch studies. Hydrological Science and Technology 9:145–190.