Spatial and Temporal Relationships of Erosion from a Degraded Catchment in Semiarid New Mexico

Bradford P. Wilcox[1], Craig D. Allen[2], David D. Breshears[3] and Rebecca Oertel[2]

[1]Rangeland Ecology and Management, Texas A&M University, College Station, Texas USA, bpwilcox@tamu.edu; [2]U.S . Geological Survey, Jemez Mountain Field Station, Los Alamos, New Mexico USA, craig_allen@usgs.gov; [3]School of Natural Resources, The University of Arizona, Tucson, Arizona USA, daveb@ag.arizona.edu

Resume

Vast tracts of semiarid rangelands across the globe are highly degraded. Remarkably, however, we have relatively few studies that have documented the rates of erosion and runoff on these landscapes and how these may change with scale. In this study, we report on results of a decade long study where we have made continuous and multiple scale measurements of runoff and erosion from a highly degraded catchment in semiarid New Mexico. Erosion is being determined at the scale of the small plot (1 m^2), sub catchment (300-1000 m^2) and catchment (1 ha) scale. Runoff is measured at the small plot and catchment scales. We are finding that runoff makes up on average less than 3% of the water budget at the catchment. At the small plot it is about 3 times higher. Erosion, by contrast does not decrease with scale of measurement, which we hypothesize is due to higher amounts of interrill and channel erosion at the larger scales. On average, erosion rates were around 10,000 kg/ha/year

Introduction

This paper summarizes and presents the major findings of an investigation examining runoff and erosion in a degraded piñon-juniper woodland in New Mexico. Erosion may represent a major loss of resources from many landscapes—particularly degrading semiarid landscapes such as the one examined in this study. In these landscapes, large and rapid soil erosion may exhibit complex and non-linear behavior, particularly in relation to scale responses (Allen and Breshears 1998, Breshears and Allen 2001). For this reason it is important to understand the scale relationships of erosion and the runoff that produces it. Understanding erosion dynamics will help quantify and manage soil carbon inventories. In addition observations in this study provide insight into scale relationships of runoff and erosion in degraded landscapes, providing a stronger basis for making predictions for runoff and erosion.

Materials and Methods

This study was conducted in a semiarid piñon-juniper woodland, at a 1.09 ha catchment known as Frijolito, within the Bandelier National Monument, on the Pajarito Plateau in northern New Mexico. Elevation on the site ranges from 1970-1990 m and average slope gradient is around 10%. The Frijolito Catchment shows abundant evidence of accelerated erosion including mostly bareground intercanopy areas, soil pedistalling, extensive but shallow hillslope channels, exposed subsoil horizons, and depositional features. Deep incision or gully features are not present on the catchment, but there is extensive gullying in adjacent catchments. The site was selected as being representative of a degraded piñon-juniper landscape that is common on the Plateau in contract to more stable piñon-juniper sites that also exist on the Plateau as described in Wilcox et al. (2003)

Until recently, about half of the catchment had a canopy of woody vegetation—either piñon (*Pinus edulis)* or juniper (*Juniperus monosperma)*. A recent drought, however, has resulted in the death of all of the piñon. Ground surface is mostly bare soil or rock. Beneath the canopy cover it is mostly needle litter. The site has undergone considerable transformation in just the last century as a result of land use and climatic perturbations. The site was dominated by an open ponderosa pine (*Pinus ponderosa)* forest until the late 1800s, when when livestock grazing and an associated reduction in fire frequency (from both fire suppression and reduced ground fuel) allowed piñon and juniper to markedly increase in density. The growing piñon-juniper population likely contributed to further decline in herbaceous cover as because of competitive demand for water and nutrient resources.

Three line intercept transects (Mueller-Dombois and Ellenberg 1974) along the contour and across the width of the catchment, at high-, mid- and low-elevation positions were conducted. The transects, which measure 50m, 65m and 40m in length are measured by stretching a fiberglass tape along the ground between permanently marked endpoints. Surface cover recorded every 1-cm. Categories include plant species, bare soil, rock, litter, wood, cryptogamic crust. Vegetation transects are conducted each year. In addition a detailed survey has been conducted locating each tree on the catchment.

Runoff was measured at two scales: the catchment (10900 m^2) and microplot ($1m^2$). Individual runoff events from the catchment are measured using a flume installed in a bedrock-floored segment of the main channel. In 1995 a network of 12 microplots (1 m^2) were installed. Each plot is equipped, at its downstream end with a gutter that catches the runoff and channels it into a bucket set into the ground. Ten of the intercanopy plots were on tuff residua soils and one of the plots was on a pumice derived soil. One plot was located under the canopy of a juniper tree.

Erosion was estimated at three scales: the catchment, the sub-catchment and the microplot. Within the catchment we established 4 sub-catchments which are outlined in Figure 1. At the catchment and sub-catchment scale, sediment coming off the area is trapped in a pit at the base of each outlet. At the microplot scale, sediment concentration of runoff was determined from a 1 liter sample collected following each runoff event.

Results

Since 1993, annual precipitation has averaged around 400 mm and has varied from 200 – 600 mm/year. The years of 2000-2003 have all be below average with precipitation in

2001 and 2002 being particularly low. On average there is a pronounced increase in precipitation during the summer monsoon months of July, August and September. The duration and magnitude of drought conditions during 2001 and 2002 are especially apparent when comparing actual monthly precipitation with average.

Runoff made up a small portion of the water budget, making up only 3% or less of the annual water budget. About 85% of the runoff that did occur resulted from convectional thunderstorms in the summer monsoons. The remainder came during fall frontal storms. There was no snow melt generated runoff at the catchment scale. Although runoff was a relatively small percentage of the water budget it did occur quite frequently. Runoff was measured from the catchment outlet about 50 times during the observation period. Most runoff events were very small with over half of the total runoff occurring during 8 events.

Even though runoff was quite small, large amounts of sediment are leaving the catchment. Annual sediment loss varied from around 70 to 20,000 kg/ha with average annual sediment loss making up around 6000 kg/ha.

We have multiple scale estimates of runoff and sediment loss within the catchment. Scales of measurement for sediment include (1) microplot (2) subcatchment and (3) catchment. For runoff we have measurements on two scales—that of the microplot and the catchment. A comparison of individual runoff events for each scale is given in Figure 1. The microplot value represents a weighted average of the canopy, pumice and tuff microplots and is computed on the basis of the relative coverage of each category. From Figure 1, we see that runoff from the microplots was on average about 4 times higher than that from the catchment and the relationship seems to be fairly robust.

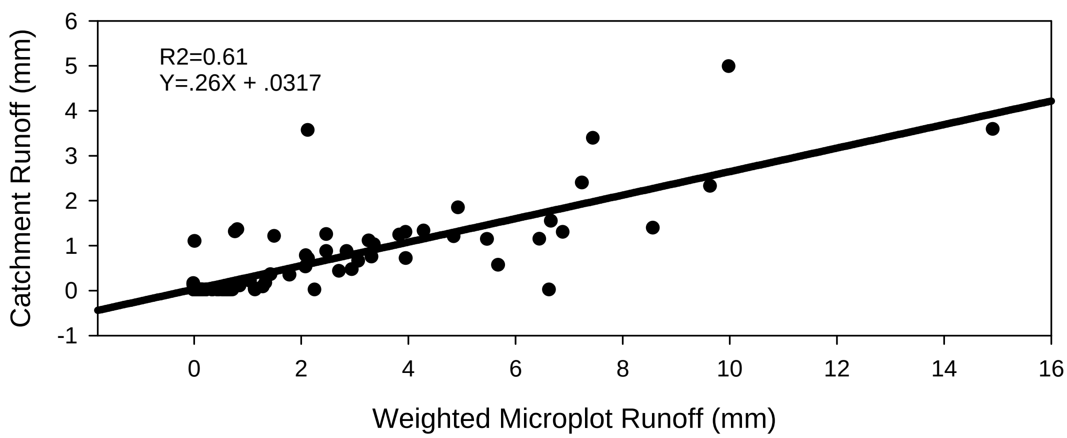

Figure 1: A comparison of runoff from the catchment vs that from the microplots.

Erosion, by contrast, did not diminish with an increase in scale. Our estimate of erosion from the the catchment was comparable to that from the sub-catchments. Measured loss

Print

Proceedings

rates were lower in the intercanopy plots (which did not include bedload dropped into the collection gutters) than either the subcatchment or catchment scales.

Discussion and Conclusions

In this study, we have been monitoring naturally occurring runoff and erosion from a small semiarid catchment that is eroding at high rates. The unique aspect of this study is that we are collecting information at multiple scales. Our results indicate that, as expected, estimates of runoff at the plot scale are considerably higher that that measured at the catchment scale. This indicates that runoff is being redistributed and stored within the catchment. We do not know where this storage is occurring. Sediment on the other hand does not diminish appreciably with scale. We are finding that the amount of sediment measured at the catchment scale is at the same order of magnitude as that measured at smaller scales. We suspect that this is a consistent attribute of other degrading landscapes in semiarid environments.

Literature Cited

Allen, C. D., and D. D. Breshears. 1998. Drought-induced shift of a forest-woodland ecotone: Rapid landscape response to climate variation. Proceedings of the National Academy of Sciences of the United States of America **95**:14839-14842.

Breshears, D. D., and C. D. Allen. 2001. The importance of rapid disturbance-induced losses in carbon management and sequestration. Global Ecology and Biogeography **10**:in press.

Mueller-Dombois, D., and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons, New York, London, Sydney and Toronto.

Wilcox, B. P., D. D. Breshears, and C. D. Allen. 2003. Ecohydrology of a resource-conserving semiarid woodland: effects of scale and distrubance. Ecological Monographs **73**:223-239.